115/34.5KV Solar Plant & Substation Design Project

DESIGN DOCUMENT

Team Number: 41

Client: Black & Veatch

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1. Introduction

1.1 PROBLEM STATEMENT

Nowadays, the world faces growing concerns over climate change and the increase of non-renewable energy resources, the need for sustainable energy solutions has become increasingly urgent. Traditional energy sources, such as coal and natural gas, contribute significantly to environmental degradation and greenhouse gas emissions. As global attention shifts toward renewable energy to mitigate these effects, large-scale solar power plants have emerged as a crucial solution. The 115/34.5 kV Solar Plant & Substation Senior Design Project will be implemented in Luna County, New Mexico. Our clients Black & Veatch aims to address the challenges associated with transitioning to cleaner energy. Black & Veatch is a consulting company and working in collaboration with us ISU students (group41) for designing this solar plant to generate clean, sustainable electricity that can be efficiently integrated into the local power grid. Luna County, with its abundant solar resources, provides the ideal environment for implementing solar energy on a large scale.

This project not only contributes to minimizing carbon emissions or provide job opportunities in New Mexico, but also supports the global shift toward renewable energy. Using engineering concepts, we will implement an additional way to generate renewable energy and integrate it into the electrical systems by designing a 60MW solar farm and substation. We will be focusing on designing the solar plant for the first semester, then work on the substation for the second semester.

1.2 INTENDED USERS

1.2.1. Utility Companies

- Description: Utility companies responsible for distributing electricity to residential, commercial, and industrial sectors.

- Need: As part of the energy transition, utility companies require reliable, sustainable power sources to meet demand, reduce emissions, and comply with renewable energy regulations.

- Benefit: The solar plant will provide a consistent, renewable power supply that utility companies can distribute to their customers. This supports their goals of reducing environmental impact while ensuring a stable energy supply. Additionally, utility companies can benefit from lower operational costs due to the long-term savings associated with solar energy.

1.2.2. Black & Veatch Clients

- Description: Corporations, municipalities, or governments that engage Black & Veatch to develop renewable energy solutions.

- Need: These clients seek to invest in sustainable infrastructure projects that align with their environmental goals and corporate social responsibility initiatives. They also require innovative, cost-efficient designs that can be scaled or replicated for future projects.

- Benefit: Through this project, clients of Black & Veatch will gain a model for developing large-scale solar plants, benefiting from the company's engineering expertise and track record in renewable energy.

1.2.3. Local Communities in Luna County

- Description: Residents and businesses in the Luna County region who will directly benefit from the availability of clean energy.

- Need: Access to affordable, reliable, and clean electricity is a growing concern for local communities, especially in regions where energy costs are high and non-renewable sources dominate.

- Benefit: The solar plant will provide local residents and businesses with a reliable source of clean electricity. This can lead to lower energy bills, reduced dependence on non-renewable resources, and a smaller environmental footprint for the community. The project also enhances local job opportunities during the construction and operation phases.

2. Requirements, Constraints, And Standards

2.1. REQUIREMENTS & CONSTRAINTS

- Equipment sizing calculations (solar panels, inverters, etc) – Excel files
- Solar layout drawings – Bluebeam/CAD/PDF editor
- Solar panel string sizing design – Excel files
- Electrical layout drawings (substation equipment) – Bluebeam/CAD/PDF editor
- Grounding analysis and ground-grid developed with IEEE-80 – Excel files
- Additional calculations (AC, DC, lightning protection, etc.) – Excel files
- Simulation of designed substation – SIMULATION SOFTWARE – STUDENT LICENSE [ETAP/SKM/ASPEN]
- Load Flow Analysis / AC Arc Flash Study / Protection Element Analysis – SIMULATION SOFTWARE – STUDENT LICENSE [ETAP/SKM/ASPEN]
- Creation of solar/substation conceptual design-optimizing tool – Microsoft Access/TBD

2.2. ENGINEERING STANDARDS

1. **NEC2020- (National Electrical Code)**

   This is a comprehensive set of safety standards developed to ensure safe electrical design, installation, and inspection practices across a wide range of electrical systems, including substations. We believe it is relevant to our project because it covers wiring and protection, equipment for general use, grounding, and bonding, along with other electrical installations. The goal is to protect people and property from electrical hazards by defining standards that minimize the risk of fires, electrical shock, and failures in power systems.

2. **IEEE 1547.3-2023**

   This standard focuses on the **interconnection of distributed energy resources (DERs),** such as solar arrays with the electrical grid. We believe that this is relevant to our project because according to our model, we might potentially have 15 solar arrays in our design project and this standard will ensures that our solar plants can connect to the grid while maintaining stability. In addition, the standard addresses how to keep voltage levels within acceptable limits during power transfers to and from the grid, ensuring reliable and safe grid operations, especially with increasing renewable energy integration.
3. **IEEE 2778-2020**

   This standard guides the **grounding system design for utility-scale photovoltaic (PV) solar power plants**. Grounding is crucial for ensuring safety and operational integrity by minimizing the risks of electrical faults, overvoltage, and shock hazards. We believe that this standard is relevant because it is designed for solar power plants larger than 5 MW, (which is our case) helping utilities design safe and efficient grounding systems that comply with regulatory requirements and improve the overall resilience of the plant.

After discussing with the team, some of my team members have chosen other standards, such as **IEEE 519-2014**, which focuses on harmonics in electrical systems. This is critical in managing the power quality in our solar plant. Others have also referenced **IEC 62109**, which deals with the safety of power converters used in solar installations, ensuring that inverters and similar equipment meet global safety requirements. Finally, based on the above standards, we plan to make the following modifications to our project design:

- **Grounding system adjustments**: We will incorporate the guidelines from **IEEE 2778-2020** to ensure that our grounding system is strong enough for utility-scale operation, with a special focus on safety during fault conditions.
- **Grid interconnection features**: We will apply **IEEE 1547.3-2023** to properly ensure that our solar plant maintains voltage stability and power quality while exporting power to the grid.
- **NEC 2020 compliance**: We will make sure that all electrical installations within the substation conform to **NEC 2020** to prevent electrical hazards, optimizing the layout and wiring based on safety standards.

3.1. Project timeline:

The Gantt chart will provide a visual representation of the schedule, highlighting the duration and sequence of each task within the project's timeframe. The chart should be referenced and summarized within the text, emphasizing key milestones and deliverables across both semesters, ensuring clear alignment between tasks and the project's overall objectives.

GANTT CHART

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
9/12/2024	9/12/2024	9/19/2024	10/3/2024	10/10/2024	10/17/2024
M T W R F S Su	M T W R F S Su	M T W R F S Su	M T W R F S Su	M T W R F S Su	M T W R F S

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	TASK COMPLETE
SOLAR PLANT					
Documentation					
Weekly agenda	All	9/12/2024			☑
Meeting minutes	All	9/12/2024			☑
Weekly report	All	9/12/2024			☑
Presentation slides	All	9/12/2024			☑
Research					
Utility-grade Solar panels	Sergio	9/12/2024	9/19/2024	7	☑
Combiner boxes	Mohamed	9/12/2024	9/19/2024	7	☑
Utility-grade Solar Inverters (skids)	Andrew	9/12/2024	9/19/2024	7	☑
Safety moment	Ben	9/12/2024	9/19/2024	7	☑
Substation design overview	Sergio	9/12/2024	9/19/2024	7	☑
Land Comparison	David	9/12/2024	9/19/2024	7	☑
Component Selection					
Solar component	David	9/19/2024	9/26/2024	7	☑
Substation component	All	9/19/2024	9/26/2024	7	☑
Solar farm and Substation Location	Sergio	9/19/2024	9/26/2024	7	☑
Cost Estimation	All	9/19/2024	9/26/2024	7	☑
Cost Analysis	Dallas	10/3/2024	10/10/2024		☑
Array Parameter Tool					
String size	All	9/19/2024	10/18/2024	30	☐
Electrical rack size	All	9/19/2024	10/18/2024	30	☐
CB capacity	All	9/19/2024	10/18/2024	30	☐
Array Design	Ben	9/19/2024	11/1/2024	53	☐
Array size	Ben	9/19/2024	11/1/2024	53	☐
Total equipment	David	9/19/2024			☐
Total cost and budget	Andrew	10/10/2024			☐
Total power (AC & DC)	All	10/10/2024			☐
Voltage drop calculation	All	10/10/2024			☐
Solar panel design					
Solar panel drawings	Dallas	10/10/2024	11/1/2024	22	☐
Solar layout	All	10/10/2024	11/1/2024	22	☐
Simulation					
Requirements					☐
Simulation					☐

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
1/20/2025	1/27/2025	2/3/2025	2/10/2025	2/17/2025	2/24/2025
M T W R F S Su	M T W R F S Su	M T W R F S Su	M T W R F S Su	M T W R F S Su	M T W R F S S

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	TASK COMPLETE
SUBSTATION					
Documentation					
One Line					☐
Three Line					☐
AC Schematics					☐
DC Schematics					☐
Wiring Diagrams					☐